

VIRTUAL LAB PRACTICE FOR QUANTITATIVE ANALYSIS OF METALS IN POLLUTED SOILS

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Abstract

From 2011, the Technical University of Madrid, Spain (Universidad Politécnica de Madrid, UPM) has been developing, initially under different educational innovation projects, several virtual labs, which are currently managed by GATE (Gabinete de Tele-Educación) of UPM.

Within the UPM virtual world, and specifically in the Chemistry Experimentation virtual lab, a lab practice for the determination of metals in polluted soils by sample digestion in a microwave oven and subsequent analysis by ICP-AES is under development.

This virtual lab practice is intended to be used for the first time during this academic course (2014-2015), with students of third year of the Civil Engineering Degree (School of Civil Engineering, UPM), as a part of the lab practice of the subject "Environmental Science".

Keywords: Virtual lab, Chemistry, metals, polluted soils, students of Civil Engineering Degree.

1 INTRODUCTION

Virtual labs are important teaching tools that allow students to perform lab practices whose implementation is few possible, for different reasons.

The use of a 3D environment, where users manage avatars in a virtual world, emerged in the UPM in 2011, as an Educational Innovation Project called "*PEIA-UPM: Plataforma de experimentación para los estudios de Ingeniería y Arquitectura de la UPM*" (Experimentation platform for Engineering and Architecture studies in UPM). In this project, which was extended during the academic course 2011-2012, several virtual lab were successfully developed: Remote Laboratory of Electronics [1], Agroforestry Biotechnology, Science and Engineering of Materials, and Control of Irrigations. Our Educational Innovation group (ATANI) participated in this project with the sub-project IE-105 815 144 [2], for the development of the Chemistry Experimentation virtual lab, which in the UPM virtual lab service, managed by the Gabinete de Tele-Educación of UPM (GATE) [3].

The UPM virtual lab service is a platform aimed at students and teachers for performing virtual lab practices. This platform is built on the open code software OpenSim (Open Simulator), which creates and manages 3D virtual worlds, which are accessible through a 3D viewer, and the language LSL (Linden Scripting Language), which provides its own functionality to the objects. Virtual labs are housed in local servers of the project responsible teachers, whereas OpenSim allows managing independent or connected regions by a grid, GridLab UPM, which is a common system that facilitates the location of the different labs housed in the virtual lab space of UPM, linking and technically managing them in an integrated manner. Therefore, the architecture is decentralized.

Apart from lab practices based on simulations, it is also possible to perform lab practices in which the avatar can interact realistically with instruments or external devices. This is due to a Web service and an application made with the development environment LabView from National Instruments [3].

In order to access the UPM virtual world, it is initially necessary to create an avatar, with the name of the user, an email direction and a password [3]. When entering the platform or GridLab UPM (through a 3D viewer, for example Firestorm), the avatar is in a central welcome area, consisting of central buildings and a virtual meeting point. In addition, there is a region or island for every virtual lab project, where the avatar can come across and interact with other users in different sites, such as virtual meeting rooms, video rooms, etc. A map of the UPM virtual world is shown in Fig. 1.



Figure 1. Map of the UPM virtual world.

The Chemistry Experimentation virtual lab was initially formed by one hexagonal building, in which the avatar can access different audiovisual materials, and there is a lab where basic operations and simple experiments can be carried out. Later, the initial aims of this virtual lab were extended, and a lab practice for the determination of metals in polluted soils by sample digestion in a microwave oven and subsequent analysis by ICP-AES is being developed, which is the objective of this work. This technique allows the performance of multielement quantitative analysis at trace levels, although its use requires trained technicians and its cost is high due to argon consumption, which makes it difficult to use it with the students. Although we know that a Civil Engineer is not going to carry out this kind of analysis, in our opinion, this must be a part of their university formation, since it may provide them with knowledge and a real vision of the importance of the quality of this type of results, which we think it might improve the environmental awareness of the future Civil Engineers. Therefore, it was necessary to adapt the available spaces to the specific requirements of the lab practice, so two more buildings have been created: one of them is designed for the sample digestion by microwave oven, and the other one for the analysis by ICP-AES. This separation in two buildings tries to reproduce the configuration of a real chemistry lab, where sample preparation and analysis are usually performed in two different rooms. An aerial view of the three hexagonal buildings that form the Chemistry Experimentation virtual lab is shown In Fig. 2.

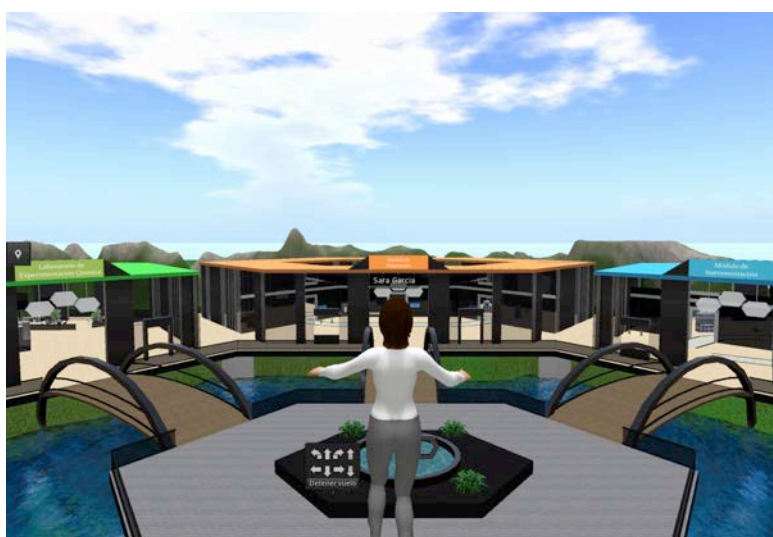


Figure 2. Aerial view of the buildings that form the Chemistry Experimentation virtual lab.

2 DESIGN AND DEVELOPMENT OF THE VIRTUAL LAB PRACTICE

From the entrance of the central building (Sample preparation building), the avatar can access three rooms: analytical balance, hood, and microwave oven and fridge (sample treatment room, with microwave oven, and sample conservation in the fridge). A general view of the entrance of the Sample preparation building is shown in Fig. 3.

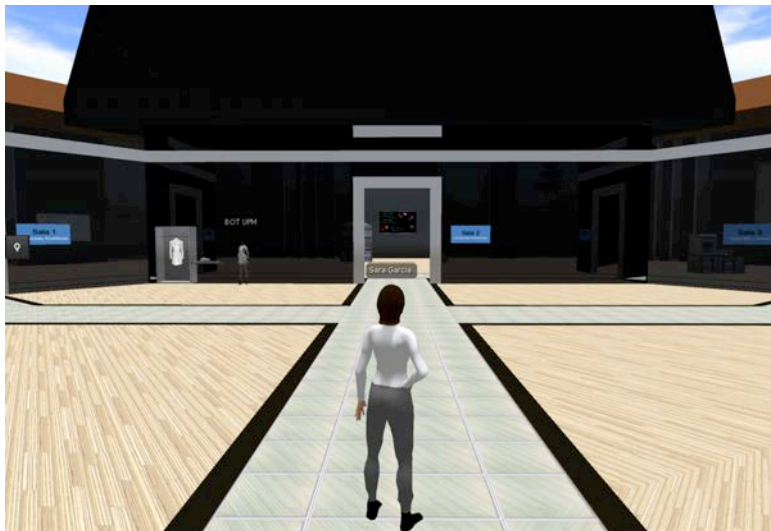


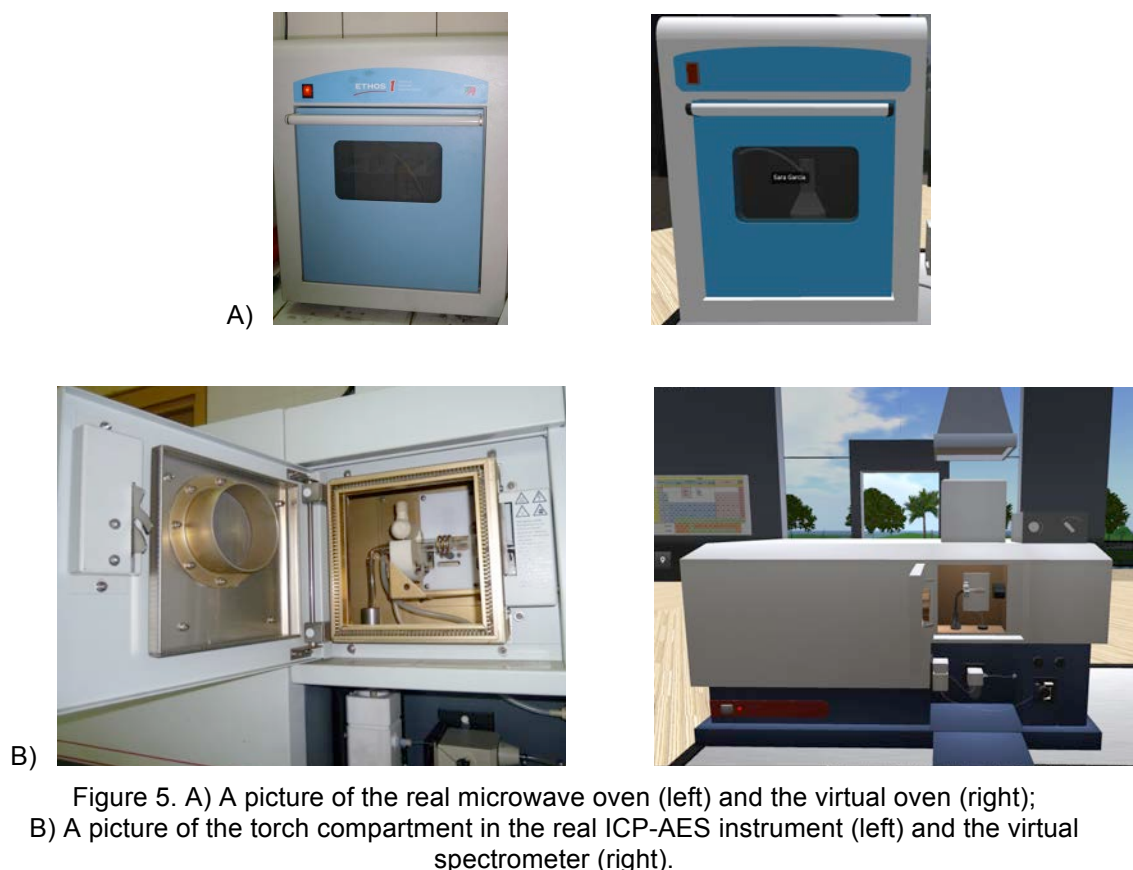
Figure 3. Entrance of the Sample preparation building, with access to the analytical balance, hood and microwave oven and fridge rooms.

In order to take into account the safety instructions followed in a real Chemistry lab, before beginning the lab practice, the avatar is welcomed by a Bot UPM, who invites him to get a lab coat and gloves, as can be observed in Fig. 4.



Figure 4. A Bot UPM welcomed the avatar at the beginning of the lab practice, and invites him to get a lab coat and gloves.

To develop the virtual lab practice, it has been necessary to create different types of materials, apparatus and instruments, with many details that give them a most real aspect. For this purpose, the whole experimental procedure was thoroughly photographed, and from these pictures and further explanations, all the objects have been created. As examples, the real microwave oven and the virtual oven, as well as the torch compartment in the real ICP-AES instrument and the virtual spectrometer are shown in Fig. 5A and 5B, respectively.



The virtual lab practice begins in Room 1: Analytical balances, where the avatar must get the soil sample from the lab cabinet and weight three replicates of the sample, in the corresponding microwave vessels, as can be observed in Fig. 6.

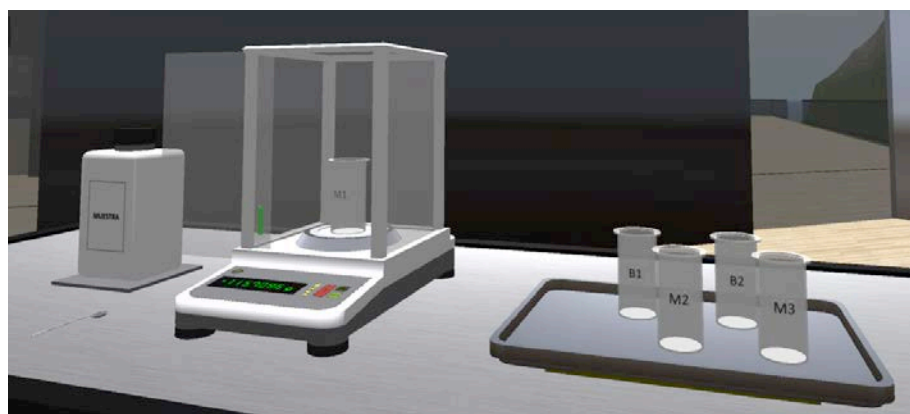


Figure 6. The avatar gets the soil sample and weights three replicates of it in Room 1: Analytical balances.

Then, the avatar must get the tray with the microwave vessels and go to Room 2: Hoods, where, in a hood, it adds the corresponding digestion mixtures (hydrochloric and nitric acids) to the vessels, closes them with the Teflon tops and puts on them the safety valves, as can be seen in Fig. 7.

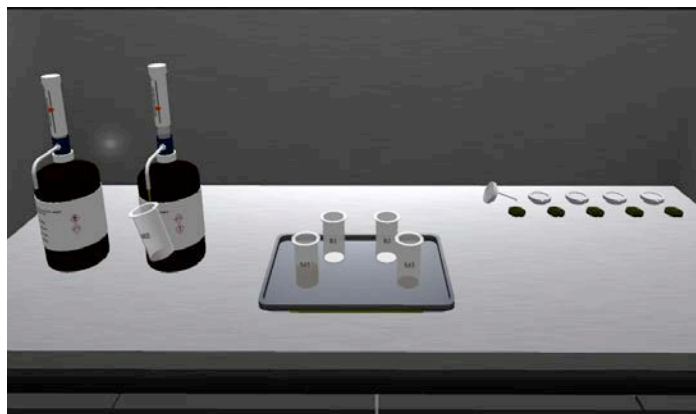


Figure 7. In a hood in Room 2: Hoods, the avatar adds the corresponding digestion mixtures to the vessels, closes them with the Teflon tops and puts on them the safety valves.

Later, the avatar gets again the tray, now with the microwave vessels closed, and goes to Room 3: Microwave oven and fridge, in order to put the vessels in their corresponding protection covers, introduce them in the microwave oven and run the digestion method.

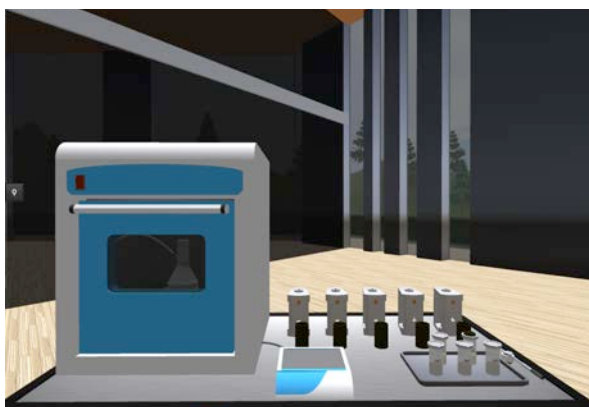


Figure 8. In Room 3: Microwave oven and fridge, the avatar puts the vessels in their corresponding protection covers, introduces them in the microwave oven and runs the digestion method.

Once the samples are digested (three replicates of the soil sample and two method blanks), the avatar comes back to Room 2: Hoods (with the tray in its hands), and in a hood, the microwave vessels are opened and the samples are filtered and diluted up to the final volume with deionized water (previously, the internal standard (Y) has been added).



Figure 9. After sample digestion, the avatar comes back to Room 2: Hoods to open the microwave vessels and filter the samples, add the internal standard and dilute the samples up to the final volume.

With all these above mentioned steps, the sample preparation part of the virtual lab practice is completed. Then, the practice continues with the second part, consisting in the sample analysis by ICP-AES, which is carried out in the building on the right (Instrumentation building), from whose entrance, the avatar can access two rooms: hood (for the preparation of the calibration standards) and ICP (for the sample analysis by ICP-AES). A general view of the entrance of the Instrumentation building is shown in Fig. 10.



Figure 10. Entrance of the Instrumentation building, with access to hood and ICP rooms.

Thus, the second part of the virtual lab practice begins in Room 4: Hoods, where the avatar prepares the calibration standards of the elements analyzed (As, Cd, Cr, Cu and Pb) in a hood, as can be seen in Fig. 11.

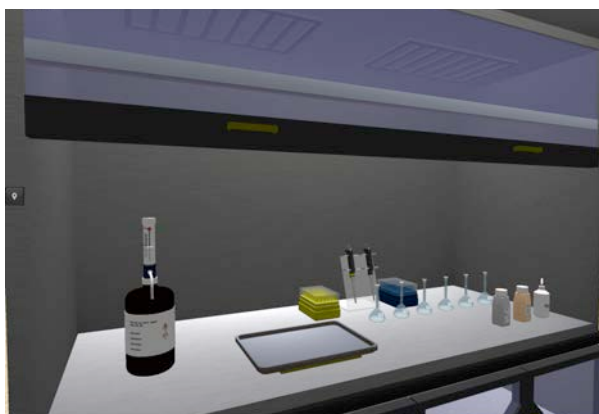


Figure 11. The avatar prepares the calibration standards in a hood, in Room 2: Hoods.

Finally, once the calibration standards are prepared, the avatar brings them, as well as the samples digested in the first part, to the ICP-AES instrument in Room 5: ICP, where the analysis of the samples is performed, using a simulation of the software of the spectrometer (Fig. 12).

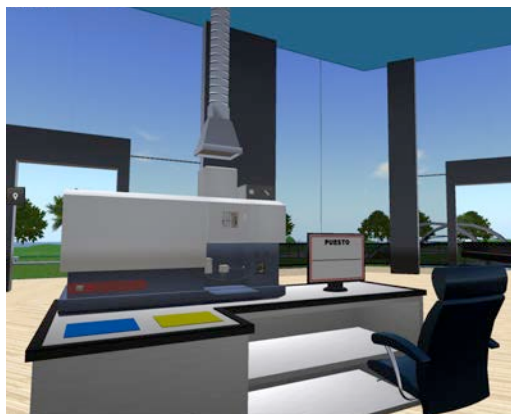


Figure 12. Samples are analyzed by ICP-AES, in Room 5: ICP.

3 APPLICATION AND USE OF THE VIRTUAL LAB PRACTICE

During the development process of the virtual lab practice, two pilot experiences have been carried out with volunteer students. These tests have allowed fixing bugs and adding enhancements, in order to make the experimental procedure of the lab practice easier to follow. Nevertheless, it will be surely necessary to continue making improvements, as the students use the virtual lab and contribute their own ideas about it.

This virtual lab practice has been included in the program for the academic course 2014-2015 of the subject "Environmental Science" (third Degree year, second semester, around 180 students) of the Civil Engineering Degree (School of Civil Engineering, UPM). Therefore, its use is planned for the first time during the second semester of this academic course.

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